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## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification <sup>5</sup> :</b> <b>C12N 15/29, 15/82, 5/10</b> <b>A01H 5/00, A01N 65/00</b>	<b>A1</b>	<b>(11) International Publication Number:</b> <b>WO 92/21757</b> <b>(43) International Publication Date:</b> 10 December 1992 (10.12.92)
<b>(21) International Application Number:</b> PCT/EP92/01214 <b>(22) International Filing Date:</b> 29 May 1992 (29.05.92)  <b>(30) Priority data:</b> 91401421.2 30 May 1991 (30.05.91) EP <b>(34) Countries for which the regional or international application was filed:</b> GB et al.  <b>(71) Applicant (for all designated States except US):</b> PLANT GENETIC SYSTEMS, N.V. [BE/BE]; Kolonel Bourgstraat 106, B-1040 Brussels (BE).  <b>(72) Inventors; and</b> <b>(75) Inventors/Applicants (for US only) :</b> VAN DER EYCKEN, Walter [BE/BE]; Denderhoutembaan 261, B-9400 Ninove (BE). NIEBEL, Andreas [DE/BE]; Savaanstraat 43, B-9000 Gent (BE). INZE, Dirk [BE/BE]; Driesstraat 18, B-9310 Aalst (BE). VAN MONTAGU, Marc [BE/BE]; De Stassartstraat 120, B-1050 Brussels (BE). DE WAELE, Dirk [BE/BE]; Meerbeke 4, B-9940 Evergem (BE). PEFFEROEN, Marnix [BE/BE]; Bernard Spaelaan 97, B-9000 Gent (BE).		<b>(74) Agent:</b> PLASSERAUD, Yves; Ernest Gutmann-Yves Plasseraud S.A., 67, boulevard Haussmann, F-75008 Paris (FR).  <b>(81) Designated States:</b> AT (European patent), BE (European patent), CA, CH (European patent), DE (European patent), DK (European patent), ES (European patent), FR (European patent), GB (European patent), GR (European patent), IT (European patent), LU (European patent), MC (European patent), NL (European patent), SE (European patent), US.  <b>Published</b> <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>
<b>(54) Title:</b> NEMATODE-RESPONSIVE PLANT PROMOTERS  <b>(57) Abstract</b> <p>Nematode-responsive plant promoters, particularly useful in the production of transgenic plants which can produce fixed feeding site cells that become capable of killing, disabling or repelling nematodes or that are themselves killed or rendered unsuitable for nematodes to feed upon when nematodes infect the plants.</p>		

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NEMATODE-RESPONSIVE PLANT PROMOTERS

This invention relates to nematode-responsive promoters which can be isolated from plants infected by nematodes and which can either induce (i.e., stimulate) or repress the expression of genes or DNA fragments, under their control, at least substantially selectively in specific cells (e.g., fixed feeding site, pericycle, endodermis, cortex or vascular cells) of the plants' roots, preferably in cells of the plants' fixed feeding sites, in response to the nematode infection. The nematode-induced promoters of this invention are especially useful in transgenic plants for controlling foreign DNAs that are to be expressed selectively in the specific root cells of the plants, so as to render the plants resistant to nematodes, particularly to sedentary endoparasitic nematodes.

This invention also relates to a first or nematode-induced chimaeric gene that can be used to transform a cell of a plant and that contains a first foreign gene or DNA fragment that: a) encodes a product which, when expressed in specific cells of the plant's roots, preferably in cells of fixed feeding sites of the plant, can either kill or at least disturb significantly the specific root cells of the plant, preferably the cells of the plant's fixed feeding sites, or kill, disable or repel nematodes feeding at fixed feeding sites; and b) is under the control of a nematode-induced promoter of this invention.

This invention further relates to a cell of a plant, the genome of which is transformed to contain the first chimaeric gene and optionally a second or restorer chimaeric gene that contains a second promoter controlling

a second foreign gene or DNA fragment encoding a product that is expressed so as to inhibit or inactivate the first foreign gene or DNA fragment or the product encoded thereby in cells other than the specific cells of the plant's roots, preferably in cells other than fixed feeding site cells of the plant.

This invention yet further relates to: a) a nematode-resistant plant (such as tomato or potato) which is regenerated from the plant cell of this invention and is transformed with the first and optionally the second chimaeric genes, b) nematode-resistant plants derived from the regenerated plant and seeds of such plants, and c) plant cell cultures, all of which consist essentially of the transformed plant cells of this invention. The plants of this invention are characterized by the nematode-induced expression of the first chimaeric gene of this invention in their specific root cells, preferably their fixed feeding site cells, and either a) the substantial, preferably complete, absence of expression of the first chimaeric gene in all other plant cells or b) the substantial absence and preferably the complete absence, by expression of the second chimaeric gene of this invention, of the effects of any expression of the first chimaeric gene in all other plant cells -- thereby rendering the plants resistant to nematode infections.

This invention still further relates to a process of rendering a plant resistant to plant-parasitic nematodes by transforming the plant with the first and optionally the second chimaeric gene(s) of this invention.

### Background of the Invention

Plant-parasitic nematodes are small (generally 100-300  $\mu\text{m}$  long but up to 4 mm long, and 15-35  $\mu\text{m}$  wide) worm-like animals which feed on root, stem or leaf tissues of living plants. Nematodes are present wherever plants are cultivated. Ectoparasitic nematodes, such as the dagger (Xiphinema and Longidorus spp.), stubby-root (Trichodorus and Paratrachodorus spp.) and spiral (Scutellonema and Helicotylenchus spp.) nematodes, live outside the plant and pierce the plant cells with their stylet in order to feed. Migratory endoparasitic nematodes, such as the lesion (Pratylenchus spp.), stem and bulb (Ditylenchus spp.) and burrowing (Radopholus spp.) nematodes, live and feed inside the plant, migrating through the plant tissues. Sedentary endoparasitic nematodes, such as the root-knot (Meloidogyne spp.), cyst (Globodera and Heterodera spp.), citrus (Tylenchulus spp.) and reniform (Rotylenchulus spp.) nematodes, live and feed inside the plant, inducing specialized fixed feeding sites called giant cells, syncytia or nurse cells in susceptible plants. Such fixed feeding sites serve as food transfer cells for the various developmental stages of the nematodes. Syncytia originate in the pericycle, endodermis or adjacent cortex (Jones, 1981).

Parasitic nematodes can cause significant plant yield losses. The most striking effect of nematode infection is a general reduction in plant growth. Nematodes can act directly as plant pathogens that predispose plants to bacterial or fungal infections or as vectors of plant viruses. Plant diseases caused by nematodes include root galling, root lesions, root rot, stubby roots, stunting and

wilting. Overall average annual yield loss of the world's major crops due to damage by plant-parasitic nematodes is estimated at 12.3 % (Sasser and Freckman, 1987). Monetary losses, when all crops are considered, exceed US \$ 100 billion annually (1984 production figures and prices; Sasser & Freckman, 1987).

On a worldwide basis, the ten most significant nematode genera are the ectoparasitic Xiphinema spp., the migratory endoparasitic Pratylenchus spp., Ditylenchus spp., Radopholus spp. and Helicotylenchus spp., the sedentary endoparasitic Meloidogyne spp., Heterodera spp., Globodera spp., Tylenchulus spp. and Rotylenchulus spp. (Sasser and Freckman, 1987). Especially significant are the sedentary endoparasitic nematodes, comprising the genera Heterodera, Globodera and Meloidogyne which cause severe damage to many crops and are of major economic importance. For example, cyst nematodes (e.g., Heterodera and Globodera) cause great problems in the production of potatoes, soybeans, sugar beets, and wheat. Once cyst nematodes have infested a field, it is practically impossible to eliminate them. Meloidogyne spp. affect many species of plants (over 2,000), including most of the major crops of the world. In the tropics, root-knot is often the limiting factor in crop production. In contrast to cyst nematode infections, extensive gall formation accompanies the infection with root-knot nematodes.

Various methods have been used to control plant parasitic nematodes (Brown and Kerry, 1987). They include quarantine measures, manipulation of planting and harvesting dates, improved fertilization and irrigation programs that lessen plant stresses, crop rotation and

following, use of resistant and tolerant cultivars and rootstocks, organic soil amendments, and physical (e.g., solarization), biological and chemical control. Although quarantines are useful, especially when an infestation is first discovered, they are very expensive measures and usually cannot prevent the spread of nematodes (Dropkin, 1980). Furthermore, biological control is difficult to manage, and high quantities and repeated additions of agents are required.

Today, control of plant-parasitic nematodes relies mainly on chemical control. Nematicides used commercially are generally either fumigants (e.g., halogenated aliphatic hydrocarbons and methyl isothiocyanate precursor compounds) or non-fumigants (e.g., organophosphates and oxime-carbamates). However, the use of chemical nematicides poses an increasing number of difficulties:

A. Developing a new nematicide requires a high financial investment, and very few new nematicidal compounds have been discovered despite intensive screening efforts (Morton, 1987). As a result, only a limited number of nematicides are currently available, and new ones are increasingly expensive.

B. Nematocides are only efficient under certain agronomical and environmental conditions (Bunt, 1987), and soil and roots act as barriers, protecting plant-parasitic nematodes from nematicides.

C. Nematodes are known to rapidly invade fields, and phytonematodes are easily distributed with soil and plants. As a result, nematode control with nematicides does not persist for long but must be



repeated frequently and with relatively high concentrations of nematicides to keep nematode populations at low levels.

D. All nematicides are highly toxic. They are therefore hazardous not only to the user but also to the environment. In the USA, several nematicides (e.g., DBCP, EDB, D-D, aldicarb and carbofuran) have already been found in the groundwater (Thomason, 1987). Due to their harmful effects on humans and non-target organisms, their persistence in the soil, and their concentration in ground water, nematicides are being withdrawn from the market worldwide. As a result, there is today a real need to have new, more effective, and safe means to control plant-parasitic nematodes.

In susceptible plants, the infective second-stage juveniles of the sedentary endoparasitic nematode species invade the roots and migrate inter- and intra-cellularly through the cortex to specific regions, usually close to the pericycle, within the roots. Once the nematode has traversed the cortex, it can initiate feeding in a cortical cell, but in most cases, feeding is initiated in endodermal or pericyclic cells (Endo, 1987). Here, the juveniles settle and begin to puncture the cells surrounding heads. Then, the juveniles introduce their secretions into these cells which induces changes in the cells, thereby forming fixed feeding sites in which a large volume of cytoplasm is available to the juveniles (Endo, 1987). The growth cycle of fixed feeding sites is directly related to the further development of the nematodes. After establishment of fixed

feeding sites, the second-stage juveniles increase steadily in size and undergo three moults in quick succession. The third- and fourth-stage juveniles cannot feed, but the young females resume feeding. Thus, further changes in the cells of the fixed feeding sites are controlled by secretions produced by the females and maintained by removal of cytoplasm by the feeding females. The initiation, development and maintenance of fixed feeding sites is essential for the establishment, development and reproduction of the nematodes. The fixed feeding sites are thus critical for the survival of the sedentary endoparasitic nematodes. Without the fixed feeding sites, the nematodes would be unable to feed and reproduce and would die. The sedentary endoparasitic nematodes thus illustrate an important principle -- that the relationship between parasite and plant host depends on a continuing exchange of information by the two organisms. When the nematodes are killed, fixed feeding sites degenerate, leading to the conclusion that the maintenance of fixed feeding sites depends on the continued presence of a functional parasite. Each of the sedentary phytonematodes induces the development of fixed feeding sites upon which it feeds.

#### Summary of the Invention

In accordance with this invention are provided nematode-responsive cDNA sequences isolated from tomato plants comprising the sequences, SEQ ID no. 1, SEQ ID no. 2, SEQ ID no. 3, SEQ ID no. 4, SEQ ID no. 5, SEQ ID no. 6, SEQ ID no. 7 and SEQ ID no. 8 described in the Sequence Listing.

Also in accordance with this invention are provided nematode-responsive promoters of the tomato genes corresponding to the cDNA sequences of SEQ ID nos. 1-8, particularly:

- a) nematode-induced promoters of the genes corresponding to the cDNA sequences of SEQ ID nos. 2-8, more particularly of: i) the gene corresponding to the cDNA sequence of SEQ ID no. 7 which gene is substantially selectively expressed in fixed feeding site cells, particularly in cells within galls, and ii) the genes corresponding to the cDNA sequences of SEQ ID nos. 4 and 6 which genes are substantially selectively expressed in pericycle cells; and
- b) a nematode-repressed promoter of the gene corresponding to the cDNA sequence of SEQ ID no. 1.

Further in accordance with this invention is provided the first or nematode-induced chimaeric gene that comprises the following, operably linked, DNA sequences:

- 1) a nematode-induced promoter that is suitable to direct transcription of a foreign DNA at least substantially selectively, preferably selectively, in the specific root cells, preferably in the cells of fixed feeding sites, of a plant (at whose fixed feeding sites nematodes would feed);
- 2) a first foreign DNA that encodes a first RNA and/or protein or polypeptide which, when produced or overproduced in the specific root cells, preferably the cells of the fixed feeding sites, of the plant, either a) kills, disables or repels the nematodes when the nematodes feed from the fixed feeding sites or b)

kills the specific root cells, preferably the cells of the fixed feeding sites, or at least disturbs significantly their metabolism, functioning and/or development, thereby at least disturbing significantly, and preferably ending, the ability of the nematodes to feed from the fixed feeding sites of the plant; and

3) suitable 3' transcription termination signals (i.e., 3'end) for expressing the first foreign DNA in the cells of the specific root cells, preferably the fixed feeding sites.

Still further in accordance with this invention is provided a cell of a plant, in which the nuclear genome is transformed to contain the first chimaeric gene of this invention and preferably, when the nematode-induced promoter directs transcription of the first foreign DNA only substantially selectively in the specific root cells, preferably the fixed feeding site cells, of the plant, to also contain the second or restorer chimaeric gene, preferably in the same genetic locus; the second chimaeric gene comprises the following, operably linked, DNA sequences:

- 1) a second promoter, such as a nematode-repressed promoter, which can direct transcription of a foreign DNA in cells of the plant where the first foreign DNA is expressed, preferably at least substantially selectively in cells other than the specific root cells, particularly in cells other than the fixed feeding site cells, of the plant;
- 2) a second foreign DNA that encodes a second RNA and/or protein or polypeptide which, when produced

or overproduced in cells of the plant, inhibits or inactivates the first foreign DNA or the first RNA or protein or polypeptide; and

3) suitable 3' transcription termination signals for expressing the second foreign DNA in cells of the plant.

Still further in accordance with this invention are provided the nematode-resistant plant regenerated from the transformed plant cell of this invention, nematode-resistant plants derived therefrom and their seeds, and plant cell cultures, each of which consists essentially of the plant cells of this invention.

Yet further in accordance with this invention is provided a process for rendering a plant resistant to nematodes, particularly sedentary endoparasitic nematodes, comprising the step of transforming the plant's nuclear genome with the first chimaeric gene and optionally the second chimaeric gene of this invention.

#### Detailed Description of the Invention

Throughout this Description, the following definitions apply:

"Fixed feeding sites" should be understood as specialized feeding sites (such as giant cells, syncytia and nurse cells and, if present, galls), the formation of which is induced by sedentary endoparasitic nematodes in susceptible plants. The plant cells of such sites serve as food transfer cells for the various developmental stages of the nematodes.

"Nematode-infected plant" means a plant in which a nematode has entered.

"Giant cells" should be understood as the multinucleate plant root cells induced by nematodes such as root-knot nematodes. The multinucleate condition of each giant cell is believed to result from multiple mitosis in the absence of cytokinesis.

"Syncytium" refers to multinucleate plant root cells induced by nematodes such as cyst nematodes. The multinucleate condition of each syncytium results from cell wall dissolution between contiguous cells with preexisting nuclei.

"Nurse cells" refers to a group of six to ten uninucleated plant root cells, induced by Tylenchulus spp., which have a dense cytoplasm without a vacuole and a much enlarged nucleus and nucleolus.

"Galls" refer to a proliferation of cortical plant cells/tissue induced by nematodes. Typically, giant cells reside within galls.

"Nematode-responsive promoter" means a promoter whose action in controlling transcription of a DNA sequence (e.g., gene) in a plant is influenced -- that is, either induced (i.e., stimulated) or repressed -- by infection of the plant by nematodes and preferably is influenced selectively in specific cells of the plant's roots, particularly in cells of the plant's fixed feeding sites. A "nematode-responsive promoter"

can be either a "nematode-induced promoter" or a "nematode-repressed promoter".

"Specific cells of a plant's roots" or "specific root cells of a plant" means cells of a root tissue such as the fixed feeding sites, the pericycle, the endodermis, the cortex or the vascular tissue, preferably a) cells of the fixed feeding sites or b) cells of tissue (e.g., pericycle cells) which i) will differentiate into fixed feeding site cells upon infection of the plant by nematodes or ii) can be altered to reduce the ability of nematodes to feed at fixed feeding sites of the plant. Particularly preferred specific root cells of a plant are fixed feeding site cells.

"Homologous" refers to proteins or nucleic acids having similar sequences of amino acids or nucleotides, respectively, and thus having substantially the same structural and/or functional properties.

"Expression" means transcription and translation to a product from a DNA encoding the product.

"Foreign" with regard to a DNA sequence, such as a first or second foreign DNA of this invention, means that such a DNA is not in the same genomic environment (e.g., not operably linked to the same promoter and/or 3' end) in a plant cell, transformed with such a DNA in accordance with this invention, as is such a DNA when it is naturally found in a

cell of the plant, bacteria, animal, fungus, virus, or the like, from which such a DNA originates.

In accordance with this invention, a nematode-resistant plant can be produced from a single cell of a plant by transforming the plant cell in a known manner to stably insert, into its nuclear genome, the first chimaeric gene of this invention which comprises at least one first foreign DNA that is: under the control of, and fused in frame at its upstream (i.e., 5') end to, one of the nematode-induced promoters of this invention; and fused at its downstream (i.e., 3') end to suitable transcription termination (or regulation) signals, including a polyadenylation signal. Thereby, the first RNA and/or protein or polypeptide is produced or overproduced at least predominantly, preferably exclusively, in the specific root cells, preferably cells of the fixed feeding sites, of the plant. Optionally, the plant cell genome can also be stably transformed with the second chimaeric gene, comprising at least one second foreign DNA that is: under the control of, and is fused at its 5' end to, the second promoter which is capable of directing expression of the second foreign DNA in cells of the plant where the first foreign DNA is expressed, preferably substantially selectively in plant cells other than the specific root cells, particularly in cells other than the fixed feeding site cells; and fused at its 3' end to suitable transcription termination signals, including a polyadenylation signal. The second chimaeric gene is preferably in the same genetic locus as the first chimaeric gene, so as to guarantee, with a high degree of certainty, the joint segregation of both the first and



second chimaeric genes into offspring of the plant regenerated from the transformed plant cell. However in some cases, such joint segregation is not desirable, and the second chimaeric gene should be in a different genetic locus from the first chimaeric gene.

In accordance with this invention, the first foreign DNA, controlled by the nematode-induced promoter, encodes a first RNA and/or protein or polypeptide which, when produced or over-produced in the specific root cells, preferably the cells of the fixed feeding sites, of the plant, either: a) kills such cells or at least disturbs significantly their metabolism, functioning and/or development so as to at least disturb significantly, and preferably end, the ability of nematodes to feed from the fixed feeding sites; and/or b) kills, disables or repels any nematode(s) feeding at the fixed feeding sites. First foreign DNAs preferably encode, for example, the following which can kill the specific root cells, preferably fixed feeding site cells, or at least disturb significantly their metabolism, functioning and/or development: RNases such as RNase T1 or barnase; DNases such as endonucleases (e.g. EcoRI); proteases such as papain; enzymes which catalyze the synthesis of phytohormones, such as isopentenyl transferase or the gene products of gene 1 and gene 2 of the T-DNA of Agrobacterium; glucanases; lipases; lipid peroxidases; plant cell wall inhibitors; or toxins such as the A-fragment of diphtheria toxin or botulin. Other preferred examples of such first foreign DNAs are antisense DNAs complementary to genes encoding products essential for the metabolism, functioning and/or development of the specific root cells, preferably the fixed feeding site

cells. First foreign DNAs preferably encode, for example, the following first polypeptides or proteins which can kill or disable nematodes: the Bacillus thuringiensis toxins described in European patent publication ("EP") 303426 (which is incorporated herein by reference), collagenases, chitinases, glucanases, peroxidases, superoxide dismutases, lectins, glycosidases, antibacterial peptides (e.g., magainins, cecropins and apidaecins), gelatinases, enzyme inhibitors or neurotoxins. When the nematode-induced promoter is a pericycle-specific promoter, such as the promoter of the gene corresponding to the cDNA of SEQ ID no. 4 or 6, the first foreign DNA under the control of such a promoter preferably encodes either: a) a material such as callose or lignin which, when produced in the pericycle cells, will make the pericycle substantially impenetrable to nematodes, so as to prevent the nematodes from feeding at the fixed feeding sites or establishing other fixed feeding sites and thereby repel the nematodes from the fixed feeding sites. Plants transformed with such a first foreign DNA in a first chimaeric gene of this invention will be resistant to nematode infections either because of a nematode-induced breakdown of their fixed feeding sites, which are essential for the survival of nematodes, or because nematodes, feeding on the fixed feeding sites, will be killed, repelled or disabled by, for example, a nematode toxin produced in situ by their fixed feeding site cells.

Each of the nematode-induced promoters of this invention, particularly the promoter of the gene corresponding to the cDNA of SEQ ID no. 7, which can be used to control expression of the first foreign DNA of this invention substantially exclusively, preferably

exclusively, in the specific root cells, particularly fixed feeding site cells, of a plant, and each of the nematode-repressed promoters of this invention, which can be used to control expression of the second foreign DNA of this invention predominantly, preferably substantially exclusively, in cells other than the specific root cells, particularly cells other than the fixed feeding site cells of a plant, can be identified and isolated in a well known manner in the specific root cells, particularly the fixed feeding site cells, of the plant. For example, a suitable nematode-induced or nematode-repressed promoter can be identified and isolated in one or more plants, preferably two or more plants (e.g., tomato and potato), infected with nematodes by the following process steps:

1. searching for an mRNA which is, respectively, substantially present or substantially absent in the cells of the roots of the plant(s) after nematode infection thereof by construction of a cDNA library and differential screening;
2. isolating the cDNA that corresponds to the nematode-responsive mRNA;
3. using these cDNA as a probe to identify the regions in the plant(s) genome(s) which contain DNA coding for the nematode-responsive mRNA; and then
4. identifying the portion of the plant genome(s) that is upstream (i.e., 5') from this DNA and that codes for the nematode-responsive promoter of this DNA.

The nematode-responsive cDNA clones of step 3 of this process can also be isolated by other methods (Hodge et al, 1990). Examples of nematode-responsive promoters, which

can be obtained by this process, are the promoters of this invention which can be identified using the cDNAs of SEQ ID nos. 1-8, particularly the nematode-induced promoters which can be identified with the cDNAs of SEQ ID nos. 2-8 and the nematode-repressed promoter which can be identified with the cDNA of SEQ ID no.1. Certain of the nematode-induced promoters of this invention, such as that which can be identified with the cDNA sequence of SEQ ID no. 6, causes expression of the first chimaeric gene in all cells of a nematode-infected plant, transformed with the first chimaeric gene, but is believed to cause expression at substantially higher levels in fixed feeding site cells. For this reason, at least certain of the nematode-induced promoters are preferably combined in the first chimaeric gene with a first foreign DNA selected so that its differential expression in the specific root cells, particularly fixed feeding site cells (as compared to the other cells of the infected plant), has the desired selective effect on the specific root cells, preferably the fixed feeding site cells. Other promoters of this invention, such as those which can be identified by means of the cDNA sequences of SEQ ID no. 4 and SEQ ID no. 6, cause expression of the first foreign DNA predominantly in pericycle cells.

When the nematode-induced promoter in the first chimaeric gene of this invention is not 100% specific for the specific root cells, preferably the fixed feeding site cells, of a plant transformed therewith, it is preferred that the plant be further transformed so that its nuclear genome contains, stably integrated therein, the second chimaeric gene of this invention. The second promoter of

the second chimaeric gene is selected so that it is capable of directing transcription of the second foreign DNA to provide sufficiently high expression levels of the second RNA or protein or polypeptide to inhibit or preferably inactivate the first RNA or protein or polypeptide in all plant cells, with the exception of the specific root cells, preferably the fixed feeding site cells. An example of the second promoter is a nematode-repressed promoter of this invention, such as the promoter of the gene which can be identified with the cDNA of SEQ ID no. 1. Other examples of second promoters are: the strong constitutive 35S promoters of the cauliflower mosaic virus of isolates CM 1841 (Gardner et al, 1981), CabbB-S (Franck et al, 1980) and CabbB-JI (Hull and Howell, 1987); and the TR1' and TR2' promoters which drive the expression of the 1' and 2' genes, respectively, of the T-DNA (Velten et al, 1984). Alternatively, a second promoter can be utilized which is specific for one or more plant tissues or organs, such as roots, whereby the second chimaeric gene is expressed only in cells of the specific tissue(s) or organ(s). Another alternative is to use a promoter whose expression is inducible (e.g., by temperature or chemical factors). To control root-knot nematodes, it may be preferred that the second chimaeric gene be under the control of a gall-specific promoter.

In accordance with this invention, the second foreign DNA, controlled by the second promoter, encodes a second RNA and/or protein or polypeptide which, when produced or overproduced in cells of a plant, inhibits or preferably inactivates the first RNA, protein or polypeptide in such cells. Second foreign DNAs preferably encode, for example,

the following: barstar which neutralizes the activity of barnase (which degrades RNA molecules by hydrolyzing the bond after any guanine residue); EcoRI methylase which would prevent the activity of the endonuclease EcoRI; or a protease inhibitor which would neutralize the activity of a protease, such as papain (e.g., papain zymogen and papain active protein). Another preferred example of a second foreign DNA is a DNA which encodes a strand of antisense RNA which would be complementary to a strand of sense first RNA.

In the first and second chimaeric genes of this invention, 3' transcription termination signals or 3'ends can be selected from among those which are capable of providing correct transcription termination and polyadenylation of mRNA in plant cells. The transcription termination signals can be the natural ones of the first and second foreign DNAs, to be transcribed, or can be foreign. Examples of foreign 3' transcription termination signals are those of the octopine synthase gene (Gielen et al, 1984) and of the T-DNA gene 7 (Velten and Schell, 1985).

The cell of a plant, particularly a plant capable of being infected with Agrobacterium, can be transformed using a vector that is a disarmed Ti-plasmid containing the first chimaeric gene and optionally the second chimaeric gene of this invention and carried by Agrobacterium. This transformation can be carried out using the procedures described, for example, in EP 116,718 (29 August 1984), EP 270,822 (15 June 1988) and Gould et al (1991) [which are also incorporated herein by reference]. Preferred Ti-plasmid vectors contain the foreign DNA sequences between

the border sequences, or at least located to the left of the right border sequence, of the T-DNA of the Ti-plasmid. Of course, other types of vectors can be used to transform the plant cell, using procedures such as direct gene transfer (as described, for example, in EP 233,247), pollen-mediated transformation (as described, for example, in EP 270,356, PCT publication WO 85/01856, and US patent 4,684,611), plant RNA virus-mediated transformation (as described, for example, in EP 67,553 and US patent 4,407,956) and liposome-mediated transformation (as described, for example, in US patent 4,536,475). In case the plant to be transformed is corn, rice or another monocot, it is preferred that more recently developed methods be used such as, for example, the methods described for certain lines of corn by Fromm et al (1990) and Gordon-Kamm et al (1990), the methods described for rice by Datta et al (1990) and Shimamoto et al (1989) and the more recently described method for transforming monocots generally of PCT patent application no. PCT/EP 9102198.

The first and second chimaeric genes of this invention are preferably inserted in the same genetic locus in the plant genome. Therefore, it is preferred that the first and second chimaeric genes be transferred to the plant genome as a single piece of DNA, so as to lead to their insertion in a single locus in the genome of the plant. However, plants containing the two chimaeric genes can also be obtained in the following ways:

1. The chimaeric genes can be separately transferred to the nuclear genomes of separate plants in independent transformation events and can subsequently be combined in a single plant genome through crosses.

2. The chimaeric genes can be separately transferred to the genome of a single plant in the same transformation procedure, leading to the insertion of the respective chimaeric genes at multiple loci (cotransformation).

3. One of the two chimaeric genes can be transferred to the genome of a plant already transformed with the other chimaeric gene.

The resulting transformed plant can be used in a conventional breeding scheme to produce more transformed plants with the same characteristics or to introduce the first chimaeric gene and optionally the second chimaeric gene in other varieties of the same or related plant species. Seeds obtained from the transformed plants contain the chimaeric gene(s) of this invention as a stable genomic insert.

The Examples, which follow, describe the isolation and characterization of nematode-responsive cDNA sequences of this invention of SEQ ID nos. 1-8 and their use as molecular probes for isolating and identifying the corresponding genomic sequences. Once the corresponding genomic sequences have been identified, the promoter regions are isolated according to well-known methods as described, for example, in European patent applications ("EPA") 89401194.9 and 90402281.1.

Unless stated otherwise in the Examples, all nucleic acid manipulations are done by the standard procedures described in Sambrook et al, Molecular Cloning: A Laboratory Manual, Second Edition, Cold Spring Harbor Laboratory Press, N.Y. (1989). Oligonucleotides are



designed according to the general rules outlined by Kramer and Fritz (1988) and synthesized by the phosphoramidite method (Beaucage and Caruthers, 1981) on an Applied Biosystems 380A DNA synthesizer (Applied Biosystems B.V., Maarssen, Netherlands).

In the following Examples, reference is made to the following Sequence Listing (SEQ ID nos. 1-8) :

SEQUENCE LISTING

SEQ ID no. 1 : LEMMI 1 cDNA (Between brackets)

SEQ ID no. 2 : LEMMI 2 cDNA (Between brackets)

SEQ ID no. 3 : LEMMI 4 cDNA (Between brackets)

SEQ ID no. 4 : LEMMI 7 cDNA (Between brackets)

SEQ ID no. 5 : LEMMI 8 cDNA (Between brackets)

SEQ ID no. 6 : LEMMI 9 cDNA (Between brackets)

SEQ ID no. 7 : LEMMI 10 cDNA (Between brackets)

SEQ ID no. 8 : LEMMI 11 cDNA (Between brackets)

Example 1 : ISOLATION AND CHARACTERIZATION OF NEMATODE-RESPONSIVE cDNAs FROM TOMATO

Young tomato plants (Lycopersicon esculentum cv. Marmande) were each grown at 20° C in industrial pots under semi-sterile conditions in a 1:1 sand:soil mixture, which was sterilized by irradiation and watered daily with a filtered sterilized nutrient solution (Cooper, 1976). Plants were infected by inoculation with about 6,000 Meloidogyne incognita race 1 eggs per pot. The nematode inoculum was obtained as described by Hussey and Barker (1973). Infected and control plants were grown under identical conditions. Five weeks after inoculation, plant material was harvested from both infected and control plants, frozen under liquid nitrogen and stored at - 80°C for further processing. Total RNA was prepared from frozen

tissue (-70° C) according to Jones et al (1985). Poly (A)<sup>+</sup>RNA was isolated by oligo - dT cellulose affinity chromatography as described by Slater (1984).

In order to construct a cDNA library from infected tomato plants, mRNA was extracted from hundreds of Meloidogyne incognita race 1 induced root-knots. cDNA was synthesized using the cDNA synthesis system plus (Amersham Intl. PLC, Buckinghamshire, England). The cDNA library was constructed in plasmid pUC19 (Yanisch-Perron et al, 1985) which was electroporated in E. coli. About 3,000 randomly selected clones were individually grown in the wells of microtiter plates containing LB medium (Miller, 1972) supplemented with 100 µg/ml ampicillin. Replicas of the sublibrary were made with a replica block on Hybond N nylon membranes (Amersham) which were further treated according to Sambrook et al (1989).

First strand cDNAs, reverse transcribed from total RNA of root-knots and of control roots, were used as probes for differential screening. To this end, reproducible replicas of 3,000 individual cDNA clones were hybridized overnight at 68°C with <sup>32</sup>P-labeled probes. Subsequently, the hybridization patterns obtained with cDNA probes from root-knots were compared to those obtained with cDNA probes from control roots. Ninety-three (93) clones gave a stronger hybridization signal with the "infected" probes than with the "control" probes. These clones were labeled as "nematode-stimulated" or "nematode-induced" clones and were subjected to a second screening. Several clones gave a weaker hybridization signal with the "infected" probes than with the "control" probe, and one of these clones was

labeled as a "nematode-repressed" clone and subjected to a second screening.

The one "nematode-repressed" and eight (8) of the "nematode-stimulated" LEMMI (Lycopersicon esculentum cv. Marmande - Meloidogyne incognita race 1) cDNA clones showed pronounced differential hybridization patterns and were selected for further analysis. The following cDNA clones showed a nematode-stimulated hybridization pattern: LEMMI 2, LEMMI 4, LEMMI 6, LEMMI 7, LEMMI 8, LEMMI 9, LEMMI 10 and LEMMI 11. The following cDNA clone showed a nematode-repressed hybridization pattern: LEMMI 1. Cross-hybridization performed under high stringency conditions showed that LEMMI 6 and LEMMI 9 most likely correspond to the same mRNA.

The different cDNA clones were sequenced. According to a database search, LEMMI 8 and LEMMI 11 appeared to be an extensin. Southern blot analysis of tomato DNA performed under high stringency conditions proved the plant origin of these clones. Since root-knots contain nematodes, some of the nematode-stimulated clones could have been from nematode origin. Southern blot and northern blot analysis further showed that LEMMI 4 and LEMMI 8 belong to different multigene families. The differential hybridization patterns of the cDNA clones were confirmed by Northern blot analysis. In situ hybridization experiments on tissue sections of nematode-infected in vitro grown tomato plants using LEMMI 7, LEMMI 9 and LEMMI 10 as probes showed that: both LEMMI 7 and LEMMI 9 are predominantly expressed in pericycle cells and LEMMI 10 has high specificity for fixed feeding site cells.

**Example 2 : ISOLATION AND CHARACTERIZATION OF NEMATODE-RESPONSIVE cDNAs FROM POTATO**

Potato plants (Solanum tuberosum cv Bintje) were infected by inoculation with the potato cyst nematode, Globodera pallida. Infected and control plants were grown under identical conditions. Eight weeks after inoculation, infected roots were harvested, and RNA was prepared as described in Example 1. 5 µg of poly (A)<sup>+</sup>RNA was used as a starting material for the construction of a cDNA library. A cDNA library of 40,000 recombinant clones was obtained after ligation in the plasmid vector pUC18 (Norranders et al, 1983) and electroporation in E. coli. 3,700 of these clones were isolated and grown in microtiter wells. Subsequently, these clones were subjected to a differential screening procedure as described in Example 1 to identify nematode-repressed cDNAs and nematode-stimulated cDNAs of potato.

**Example 3: IDENTIFICATION AND CHARACTERIZATION OF OTHER NEMATODE-RESPONSIVE GENES FROM PLANTS**

For the purpose of identifying plant genes which are induced by nematodes, tobacco and Meloidogyne javanica were used as a model system. An in vitro system has been developed which allows synchronized infection by a number of nematodes and immediate analysis of resulting proteins. The system used in vitro grown SR1 tobacco plants as a starting material.

Explants consisting of an internode and a leaf were cut off tobacco plants. The explants were then put into Petri dishes (13.5 cm diameter) which contain the normal culture medium used for SR1 tobacco plants. The explants started rooting after about 5 to 7 days. After 10 days, the

roots were infected in the following way: the culture medium is carefully lifted and a solution containing approximately 1000-2000 nematode larvae (2nd larval instar) is added. This in vitro system had several advantages, including the synchronicity of the infection, the easy scoring and the possibility of stage-specific observations. Several pathogen-induced and pathogenesis-related proteins were tested using this system. A very strong induction of extensin (8-fold higher than in control roots) was observed. Subsequently, the promoter of the unique extensin gene of Nicotiana plumbaginifolia (De Loose et al, 1991) was fused to a reporter gene,  $\beta$ -glucuronidase (Jefferson et al, 1986), and transformed into tobacco. These transformed plants were analysed by means of histochemical  $\beta$ -glucuronidase assays (Peleman et al, 1989). A very localized and strong Gus-activity was observed around the fixed feeding sites.

**EXAMPLE 4 : ISOLATION OF NEMATODE-RESPONSIVE GENES CORRESPONDING TO THE NEMATODE-RESPONSIVE cDNA CLONES OF EXAMPLES 1 AND 2**

In order to isolate the genomic DNA clones carrying the regulatory sequences of the genes corresponding to the selected cDNA clones of Examples 1 and 2, a genomic library is constructed. To this end, total genomic DNA of tomato is digested with a tetra-cutter restriction enzyme in order to obtain approximately 20 kb DNA fragments. These genomic DNA fragments are then cloned in the phage vector, Charon 35 (Rimm et al, 1980).

The nematode-responsive cDNAs of Examples 1 and 2 are used as probes for screening the library. Genomic clones, which hybridize to the probes, are selected and sequenced.

Comparison of the sequences from the cDNA clones of this invention with those of the genomic clones leads to the identification of the homologous regions. At the 5' end of the homologous region of each genomic clone, the ATG translation initiation codon and TATA consensus sequence are identified in order to locate the nematode-responsive promoter region. The fact that the "TATA-box" is part of the promoter region is confirmed by primer extension.

Confirmation of the nematode-responsive promoter regions is made by use of the "inverse PCR" technology as described by Ochman et al (1988, 1989). By this method, the DNA sequences flanking a well-defined core region of each nematode-responsive gene sequence, which corresponds to the sequence of a nematode-responsive cDNA, are amplified.

**Example 5 : CONSTRUCTION OF NEMATODE-RESPONSIVE PROMOTER CASSETTES DERIVED FROM THE NEMATODE-RESPONSIVE GENES OF EXAMPLE 4**

The 5' regulatory sequences, including the nematode-responsive promoter, of each of the nematode-responsive genes of Example 4 are subcloned into the polylinker of pMAC 5-8 (EPA 87402348.4). This produces vectors which can be used to isolate single stranded DNA for use in site-directed mutagenesis. Using site-directed mutagenesis (EPA 87402348.4), sequences surrounding the ATG translation initiation codon of the 5' regulatory sequences of each of the nematode-responsive genes are modified to create a unique recognition site for a restriction enzyme, for which there is a corresponding recognition site at the 5' end of the first foreign DNA of this invention (that is to be fused to the 5' regulatory sequences in Example 6, below). The resulting plasmids each contain the newly created

restriction site. The precise nucleotide sequence spanning each newly created restriction site is determined in order to confirm that it only differs from the 5' regulatory sequences of the corresponding nematode-responsive gene by the substitution, creating the new restriction site.

**Example 6 : CONSTRUCTION OF PLANT TRANSFORMATION VECTORS FROM THE PROMOTER CASSETTES OF EXAMPLE 5**

Using the procedures described in EPA 89401194.9 and 90402281.2, the promoter cassettes of Example 5 are used to construct plant transformation vectors comprising first chimaeric genes of this invention, each of which contains the 5' regulatory sequences, including the nematode-responsive promoter, of one of the nematode-responsive genes isolated in Example 4. Each of these 5' regulatory sequences is upstream of, is in the same transcriptional unit as, and controls a first foreign DNA (from EPA 89401194.9) encoding barnase from Bacillus amyloliquefaciens (Hartley and Rogerson, 1972). Downstream of the first foreign DNA is the 3' end of the octopine synthase gene (Gielen et al, 1984). Each chimaeric gene also comprises the 35 S'3 promoter (Hull and Howell, 1987) fused in frame with the neo gene encoding kanamycin resistance (EPA 84900782.8), as a marker, and the 3' end of the octopine synthase gene.

**Example 7 : TRANSFORMATION OF TOMATO AND POTATO WITH THE PLANT TRANSFORMATION VECTORS OF EXAMPLE 6**

To obtain transformation of, and major expression in, tomato and potato by the plant transformation vectors of Example 6, each vector is inserted between the T-DNA border sequences of a Ti-plasmid carried by Agrobacterium (EPA 89401194.9 and EPA 90402281.1). In this regard, the

vectors from Example 6 are each mobilized into Agrobacterium tumefaciens C58C1 Rif<sup>R</sup> containing pMP90 (Koncz and Schell, 1986). The resulting recombinant Agrobacterium strains are used to transform tomato leaf discs using the standard procedures described in EPA 87400544.0. The resulting recombined Agrobacterium strains are also used to transform potato plants (Solanum tuberosum cv. Bintje) by means of tuber disc infection as described by Deblock et al (1987). Transformed calli are selected on a substrate containing 100 µg/ml kanamycin, and resistant calli are regenerated into plants.

Plants transformed with the nematode-induced chimaeric genes of this invention containing nematode-induced promoters, particularly the nematode-induced promoters of Example 4 identified with the cDNAs of SEQ ID nos. 2-8, quite particularly the promoter identified with the cDNA of SEQ ID no. 7, show a significantly higher degree of resistance to sedentary endoparasitic nematode infection, such as Meloidogyne incognita infection, than do non-transformed control plants. As a result, the transformed plants have significantly lower yield losses than do the control plants.

Needless to say, the use of the nematode-responsive promoters of this invention is not limited to the transformation of any specific plant(s). Such promoters can be useful in transforming any crop, such as rapeseed, alfalfa, corn, cotton, sugar beets, brassica vegetables, tomato, potato, soybeans, wheat or tobacco where the promoters can control gene expression, preferably where such expression is to occur abundantly in specific root cells, preferably in fixed feeding site cells.



Also, the use of the nematode-responsive promoters of this invention is not limited to the control of particular foreign DNAs but can be used to control expression of any gene or DNA fragment in a plant.

Furthermore, this invention is not limited to the specific nematode-responsive, preferably nematode-induced, promoters described in the foregoing Examples. Rather, this invention encompasses promoters equivalent to those of the Examples which can be used to control the expression of a structural gene, such as a first foreign DNA, at least substantially selectively in specific root cells, preferably fixed feeding site cells, of a plant. Indeed, it is believed that the DNA sequences of the promoters of the Examples can be modified by replacing some of their codons with other codons, provided that such modifications do not alter substantially the ability of polymerase complexes, including transcription activators, of specific root cells, particularly fixed feeding site cells, to recognize the promoters, as modified.

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**SEQUENCE LISTING****1. General Information**

i) APPLICANT : PLANT GENETIC SYSTEM N.V.

ii) TITLE OF INVENTION : Nematode-Responsive Plant Promoters

iii) NUMBER OF SEQUENCES: 8

iv) CORRESPONDENCE ADDRESS :

- A. ADDRESSEE : Plant Genetic Systems N.V.
- B. STREET : Plateaustraat 22,
- C. POSTAL CODE AND CITY : 9000 Ghent,
- D. COUNTRY : Belgium

v) COMPUTER READABLE FORM :

- A. MEDIUM TYPE 5.25 inch, double sided, high density 1.2 Mb floppy disk
- B. COMPUTER : IBM PC/AT
- C. OPERATING SYSTEM : DOS version 3.3
- D. SOFTWARE : WordPerfect 5.1

vi) CURRENT APPLICATION DATA : Not Available

(vii) PRIOR APPLICATION DATA : EPA 91401421.2

SEQ ID NO. 1

SEQUENCE TYPE: nucleotide  
SEQUENCE LENGTH: 1193 bp

STRANDEDNESS: double-stranded  
TOPOLOGY: linear  
MOLECULAR TYPE: cDNA to mRNA

ORIGINAL SOURCE: plant  
ORGANISM: tomato

PROPERTIES: Nematode-responsive cDNA 1  
MISCELLANEOUS: cDNA designated as LEMMI 1

TGTGNGTTGC	TCNCTCNTTG	GCNCNCCGGC	TTTNCNCTTT	NTGCTTCCGG	50
CTCGTNTGTT	GTGTGGNNTT	GTGTGNGNTT	NNCNNTTTCN	CNCNGGNNNC	100
GCTATGNCCA	TGATTACGCA	AGCTTGCAAT	CCTGCAGGTC	GACTCTAGAG	150
GATCCCCGGG	TACCGAGCTC	GCCATGGTAG	GCGGATCCTC	GAATTTCGAGG	200
ATCCGGGTATC	CATGGAGAAA	CTAGAACTCA	AATACCAAGA	GTCAGTTTCT	250
GAAGAATATC	AATGGCGTCA	CTTCAGTGCA	AAAGCCAGTT	GCACAACCAA	300
CTGTCTGCCA	AAAAACCACC	AACACTGTCA	CTTGCCACAA	GGCGAATGAG	350
CACCACTTGG	CTGACAAAAT	GAAACAGATG	ACAACCAAGA	TGTTGCACCA	400
CGACAACCAT	GGTCAGCAAT	CTGCCTGCCA	TGGAGCCAAA	ACTCAACATT	450
CAGCAGGCCA	TGGCTCCACT	GCTATTACAG	GAAATCATGG	TAGCCACTGC	500
CAGCAGACTG	CATGCCATGG	TGCAAAAAC	CAACATTCAG	CATGCCATGG	550
CTCCACTGCT	ATGCATGGAA	ATCATGCTAA	GGGACACAAC	ACTGCATGCC	600
ATGATGCTAA	ANCTCAACAT	TCAGCNGGCC	ATGGCTCCAC	TGTTGGGCAT	650
GGAAATCATG	CCAAGGGCAC	AACNCTGCAT	GCCATGGMAC	CAAAWCTCAA	700
CATTCAACAT	GCCATGGTCC	ACCGCTACTC	ATGGAAAYAT	GCTAWKNNNA	750
GATNACTGNA	TGCATGGCAN	NAAAAC	NATTCAANAG	GCCATGGCTC	800
CACTGCTATG	CATGGAGNTT	ATGCTAACCA	CGGACAGNAC	ACTGCAAGTC	850
ATGGCTCCAC	TGCTGTGCAT	GGAAGTCATG	GTAGCCACAA	CCAGCAGACT	900
GTGTCCATGG	CTCAAAGAAG	GAAGGGGGCA	TCATGCATAA	GATAGGTAGT	950
CAGCTGAAGA	CCATCGGGAA	AAAGAAGAAC	AAAGATGGAC	ACTGCAGAGA	1000
TGGCAGTGAC	AGCAGCGACA	GCAGCAGCAG	CAGCGATGAT	GAGAGCGACA	1050
ATGAGAATTG	TGGAAAAAAA	AAAAACCATG	GTACCCGGAT	CCTCGAATTC	1100
ACTGGCCGTC	GTTTTACAAC	TTCGTGACTG	GGAAANCCCT	NGCGTTACCC	1150
AACTTAATNG	CCTTGCNGCA	CATCCCCCTT	NNNCCAGCTG	GGT	1193

SEQ ID NO. 2

SEQUENCE TYPE: nucleotide  
SEQUENCE LENGTH: 305 bp

STRANDEDNESS: double-stranded  
TOPOLOGY: linear  
MOLECULAR TYPE: cDNA to mRNA

ORIGINAL SOURCE: plant  
ORGANISM: tomato

PROPERTIES: Nematode-responsive cDNA  
MISCELLANEOUS: cDNA designated as LEMMI 2

[GAATGNNNNN	NNGGGGNNNN	NNAAGNGNNA	AAGNNNAAAG	GAGAGAAAGA	50
CAAGTCAAAG	NGGAGTCAGN	AGAAGAGAAG	GATATTGNNN	AAGNNNAGAA	100
GGATAAAGAG	AAGAAAGACA	AGAAAAAAGG	GGCATCAGAC	GAAGAGAACG	150
AGCGCGAAGA	AGAGAAATGAT	GAAAAAGGTG	TGAAAAAAAA	AAAAAA[CCA	200
TGGTACCCGG	ATCCTCGAAT	CGAGGATCCG	NNNNNNATNG	CGAGCTCGGT	250
ACCCGGGGAT	CCTCTAGAGT	CGACCTGCAA	ACATGCAAGC	TTGGNGTAAT	300
CATGT					305



SEQ ID NO 3

SEQUENCE TYPE: nucleotide  
SEQUENCE LENGTH: 543 bp

STRANDEDNESS: double-stranded  
TOPOLOGY: linear  
MOLECULAR TYPE: cDNA to mRNA

ORIGINAL SOURCE: plant  
ORGANISM: tomato

FEATURES: Nucleotide 1 to 64: cloning vector sequence  
Nucleotide 65 to 88: cloning adaptor sequence

PROPERTIES: Nematode-responsive cDNA  
MISCELLANEOUS: cDNA designated as LEMMI 4

ACATGATTAC	NCCAAGCTTN	CATGCCTGCA	GGTCGACTCT	AGAGGATCCC	50
CGGGTACGAG	CNCNAATTCG	AGGATCCGGG	TACATGGCTG	GTTTTCTACG	100
AAATATATTT	TAGTAAAGCA	ATTTTTAGAA	AAACAAAGAA	GTAGAGATAC	150
TCTCCGAGAT	AAAGTAATTT	CATTAECTCA	TCTTTTGAAA	CTCACAAAGC	200
TTATGTTTTA	ACAAGCATCA	GACAGACATA	AAGCNCGAAG	GTTTTATGTC	250
TAAAGGGAAA	CAGCCCAGAT	GAATAGATAA	GGTCCCAAAT	AGTTATTAAA	300
AATAAAATAA	GTTTTCATTT	AAAAGATTAA	AAGGTATGCT	TGGAAGCAGC	350
CAGCCTTTAA	AGAAAGCGTT	GCAGCTCATT	AATTGAATAA	TAANAACCTA	400
TTGAGAATAT	ACGGGAATGA	AATAACTCAC	AAAAAACCAA	CCGAATCTTT	450
CAATATGTTA	ATAAAAAGTA	TGTCATATGG	TAGTAGAATA	TNTTGTCA NA	500
AAAATAAAAC	NAAAGAGAAA	ATCTNTTGGT	ATAAGTAGCG	AAA	543

SEQ ID NO.4

SEQUENCE TYPE: nucleotide  
SEQUENCE LENGTH: 482 bp

STRANDEDNESS: double-stranded  
TOPOLOGY: linear  
MOLECULAR TYPE: cDNA to mRNA

ORIGINAL SOURCE: plant  
ORGANISM: tomato

FEATURES: Nucleotide 1 to 8: cloning vector sequence  
Nucleotide 9 to 32: cloning adaptor sequence  
Nucleotide 33 to 482: putative Open Reading Frame  
(\*ORF\*)

PROPERTIES: Nematode-responsive cDNA  
MISCELLANEOUS: cDNA designated as LEMMI 7

GGCCAGTGAA	TTCGAGGATC	CGGGTACCAT	GGGAATTATTC	TCAACCAATG	50
GGTGAAAAAA	TCAAAGTTGA	AGGAGCAGAG	AAGAAGAACG	AAAGTTCAAT	100
TGTTTTTAAA	CTGGATTTC	ATTGTGAAGG	TTGTGCACAA	AAACTCAGAC	150
GATTCATTTCG	CCATACTCAT	GGTGTGGAAA	AAGTGAAATC	GGATTGTGAA	200
ACTGGAAAAC	TGACGGTTAA	AGGTGACGTT	GACCCTTCAT	GGCTCCGGGA	250
GAGAGTGGAG	ATCAAAACCA	AAAAGAAGGT	GGAGCTTATA	TCATCGCCGC	300
CCAAAAAGGA	CNCCGGAGAT	AAAAAGAGCG	GCGGAGATAA	AAAGTCGGTG	350
AAAAAACAGA	GGACAAGAAG	GAAGACGAGA	AGAAACCCAA	AGAGGCTCAA	400
GTAACAGTGT	GGTGGCATT	AAGATTCGGG	TGCTTGTGAT	GGATGTGCAC	450
ATAAAATCAA	ACGAGTTATT	AAAAAGATTA	AA		482

SEQ. ID. NO. 5

SEQUENCE TYPE: nucleotide

SEQUENCE LENGTH: 2610 bp

STRANDEDNESS: double-stranded

TOPOLOGY: linear

MOLECULAR TYPE: cDNA to mRNA

ORIGINAL SOURCE: plant

ORGANISM: tomato

FEATURES: nucleotides 1878 to 2434 constitute nematode-responsive cDNA

PROPERTIES: Nematode-responsive cDNA

MISCELLANEOUS: cDNA designated as LEMMI 8

ATAACAATTT	CACACAGGAA	ACAGCTATGA	CCGATGATTA	CGCCAAGCTT	50
GCATGCCTGC	AGGTCGACTC	TAGAGGATCC	CCGGGTACCG	AGCTCGAATT	100
CGAGGATCCG	GGTACCATGG	ACTCCGAAAA	TATCAGGAAT	AGCAGTGAAT	150
CGAGCGGGAG	GGCGAGCGAG	TAAGCGAGAT	CGGAGATCGG	AAGATGTCTG	200
CGGAACCACC	GCCATTTCAA	GAAGCTTCAC	GTTGTGATGT	CTGCAATTGC	250
AGCTTCAATA	CTTTCCGGCG	ACGGCACCAT	TGCAGATGTT	GCGGCCGAAC	300
ATTATGTGCT	GAACATTCAG	CAAATCAGAT	GGCCTTGCCA	CAATTGTGGT	350
TTCACCTAAG	TGTGAGAGTT	TGTGGAGATT	GTTTAAATAA	CTCCTCTCGG	400
TAAATTTCTG	CCACTATTAT	CAATGATATA	TCGTATACTT	CTCAATATTG	450
ATGCCAAATA	TGCTTTTAT	TTTGCCCAAA	TTCTAAAGTC	AGAGATGCTG	500
TCATAGAGTT	ATGAGGAATT	TATTCTTGGA	ATTCATCTT	CTCTCACCCT	550
ATTCAATCAT	AACCTCCAAT	TTTTTCAGTCA	TTAAGAATCT	CTTTTGTAT	600
GACAAAGATA	ACCCGCAGCC	GCTACCCTTT	GGGTGCACAC	AAGGCAAGTC	650
ATTAAGAAAT	TTTTATCTAG	GAAGTAATAT	TATACTCTTA	TTAGCTCATG	700
GGTGATTGCT	AACTAGTACA	TGAAAGACAA	AAAAACTGCC	ATCAAGCAGG	750
AAACACTTTA	ATATATAAAC	ACTGTTCTCA	AAACTAAAAT	AATAATAAAT	800
AAAAACCCTT	GAAAATGTTG	AAGCCCTTAT	TGCTTCATCA	TTTTTGAGAA	850
TAGAAGCTTG	AGAGTAGCAT	CCTCCCTTAT	TTGTTAAAGA	ATGTAGGGAG	900
TTGGAAACAG	TCTGAAGTGC	TTGTGATACC	ATCTGTAAGC	ACTTGGAATC	950
AGGACATAAC	AGAAATGGGT	AAATTTTGAA	AAGTAGCCAG	TTTTTGCTCT	1000
GTTTGGTGTT	TCATTGATCG	AAGGATCATC	ATATTTTCAGT	ACTGCAATAT	1050
GTTGGAAAGG	TATTACTGTT	TCATCTTTGA	GGTTTGAGGC	CATAGATTTA	1100
GTGCCCCTTG	GATTAACTCA	CTTTTAGGTG	CTTTTGTCTT	TTAAGCATTT	1150
TATAAGTTTT	GGAGGTGTTT	GGAAAGGTTA	AAAAGTGCTT	CTAAGCATTC	1200
ACTTTTTTGCT	CAAAAAAGTT	TTAAAATAAG	TCAAAAAGTCG	AATGTAGGGT	1250
ATCATCTACT	TATGACTTTT	AGCGTTTTGA	CTTATAAATT	ACTTTTATAA	1300
GCTCATCCAA	ACAGGCCCTT	GTTCAATTTAT	ACCTCCCTAA	AGATCTTTGA	1350
CGAGACTGAA	GGCTATTCTG	CATATCGGTG	TTGATAGTCT	GAAGAAAATA	1400
ATCTGCCTAT	ATACATCGAG	CTTCTTTTCA	ATTTATACAT	CATTTAACAG	1450
AATTGCTAAT	TAGTATCTTT	AATTCTTTTT	AATGACACTT	AAAATGTTTT	1500
ACATCTTTTT	ACTAATCTGA	TTCTTAGTGG	ACCCGTTGGA	GATGGCGTGA	1550
TGGCTTCTGC	AAGTGAAGTC	AATGCCCTGA	AAGATTCAAT	TTGAGCTTTA	1600
GATGTTGGTG	TCGTGGCAGA	TATCAAAACT	GAAGACACTG	TCAAGCAGAC	1650
TCCTGCTGTA	GGCATCACAG	ACTGCAAATG	TGGGATGCCT	TTGTGTATCT	1700
GCCAAGTGTC	AGCTACACCA	ACAACATCCA	TTGCTTCACA	GGAAAGGACA	1750
TATTTACTGG	CCTTCAAATG	CTTTTTGAGC	AAATGACAAT	TCCTTTATAT	1800
TTTTTTTTGA	TTCCAGCAGG	GAATTATTAT	GCCAAATCCA	ATTGTAAACA	1850
TAAATCCAAA	ACCAAAAAAA	AAAAAACTGC	TACAAGTCAC	CACCACCACC	1900
AGTGAAGCCA	TACCATCCTA	CACCCGTATA	CAAGTCTCCA	CCACCACCAA	1950
CTCCCGTTTA	CAAGTCACCA	CCATCACCAG	TGAAGCCATA	TCATCCCTCA	2000

CCAACACCAT	ACCACCCTAC	ACCAGCATAC	AAGTCTCCAC	CACCACCAAC	2050
TCCAGTCTAC	AAGTCTCCAC	CACCAACCCA	CTATGTTTCC	TCCTCTCCCC	2100
CTCCTCCCTA	CCATTACTAA	GAAGTGAGTT	TACTATATCT	GAGGAAAAGC	2150
CTAATGTTGA	GCTGAAAGAA	AGGCATTTTC	CATTTTCAAG	AAGAAAATTA	2200
TAGTAAATAA	TAAGGCTTAC	AGAAGATCAG	ACGAAGTTCT	TTTGTAGCTT	2250
CATGTTATCT	AACTAGTCTT	AGTGATATAT	TGTTTTTGTA	CTCTATTTTT	2300
ATATATTACT	TTTATGTGTC	TTTGTGTATG	TTTGCTCACT	TTCAATCTTC	2350
TTGCAAAATG	CAGAGATTAA	TTATGAGATT	ATCATGAATA	AAATAAGTTA	2400
TTACTACTCC	CATATGTTTT	AAAAAAAAAA	AAAACCATGG	TACCCGGACC	2450
TCGAGGATCC	GGGTACCATG	GCACTGGCCG	TCGTTTTACA	ACGTCGTGAC	2500
TGGGAAAACC	CTGGCGTTAC	CCAACTTAAT	CGCCTTGCAG	CACATCCCCC	2550
TNNCGCCAGC	TGGGCTAATA	GCGAAGAGGC	CCGCACCGAT	CGCCCTTCCA	2600
ACAGTTGCGC					2610

SEQ ID NO. 6

SEQUENCE TYPE: nucleotide  
SEQUENCE LENGTH: 1004 bpSTRANDEDNESS: double-stranded  
TOPOLOGY: linear  
MOLECULAR TYPE: cDNA to mRNAORIGINAL SOURCE: plant  
ORGANISM: tomatoPROPERTIES: Nematode-responsive cDNA  
MISCELLANEOUS: cDNA designated as LEMMI 9

ACCATGATTA	CNCCAAGCTT	GCATGCCTGC	AGGTCGACTC	TAGAGGATCC	50
CCGGGTACCG	AGCTCGAATT	CGAGGATCCG	GGTACCATGC	CGGTATGGTA	100
CCCGGATCCT	CGATTTCGAGG	ATCCGGGTAC	CATGTTTCGTT	TAGCACAAAA	150
CAGGCATACT	ATTCAATTCC	CTTTCGTTCC	AGAAAGCATGG	ATCTAATTGA	200
CAAGGCGAAG	AATTTTGTGT	CGGAGAAGAT	AGCCAACATG	GAGAAACCGG	250
AGGCAACCAT	CACCGACGTC	GATCTTAAGG	GGATCGGTTT	CGACGGCCTT	300
GCTTTTCACG	CTAAAGTCTC	CGTTAAGAAC	CCTTACTCTG	TTCCTATTCC	350
AATCATGGAG	ATCGATTACG	TCCTCAAAAG	CGCCACCAGG	GTAATCGCAT	400
CAGGAAGAAT	TCCAGACCCA	GGGAGCATAA	AGGCAAATGA	CTCAACCATG	450
TTAGATGTGC	CAGTGAAGGT	TCCTCACAGT	GTGCTAGTGA	GTTTGGTTAG	500
GGACATTGGA	GGAGATTGGG	ACGTCGATTA	TACCCCTGGA	TTGGGTCTCA	550
TTATTGATAT	TCCGGTCATT	GGCAACATCA	CCATTCCCCT	CTCTTATAGC	600
AGGCGAGTAT	AAGCTTCCTA	CATTGTCAGA	TTTATGGAAG	GGTGGAAGAG	650
AAGAAGAGTA	AAAAGAAGAT	GAAGAGGAGA	AAGAAGATCC	ATCAAAGGTT	700
GTGAGATAT	GAAGAGTTAT	ACCTATCTAA	TAATGTGGCT	TTAATATGCC	750
TAGTTTCTCT	TCTGTTGTTT	TAATAACATA	AAGTTTGTTT	ACCTTATAAG	800
TATCATTTC	AGGATACAAA	ATGCACAAC	TTATGAACT	CACATTACTC	850
TTATCTCACC	TGATTTGATG	ATATGAAGAT	TTGATGATGT	TAGGTTTAAA	900
AAAAAAAAAA	AAACCATGGT	ACCCGGATCC	TCGAATTCAC	TGGCCGTCGT	950
TTTACAACGT	CGTGACTGGG	AAAACCCTNN	NGTNAACCCA	ACTTAATCGC	1000
CTTG					1004

SEQ ID NO. 7

SEQUENCE TYPE: nucleotide  
SEQUENCE LENGTH: 507 bp

STRANDEDNESS: double-stranded  
TOPOLOGY: linear  
MOLECULAR TYPE: cDNA to mRNA

ORIGINAL SOURCE: plant  
ORGANISM: tomato

PROPERTIES: Nematode-responsive cDNA  
MISCELLANEOUS: cDNA designated as LEMMI 10

GGCCAGTGAA	TTCGAGGATC	CGGGTACATG	GGATGAAAAA	GGTGTGAAGA	50
AGGATAAGGA	TAAGAAACCC	AATAAGGAAA	AGAAAGAGAA	AAAGGATAAA	100
GGAAAGAAAAG	ATAAGAGCAA	AGAGGAGTCG	GAGGAAGAAG	AGAAGGATGA	150
TGTAAAAGGG	AAGAAGAAGG	ATAAAGAGAA	GAAAGATAAG	AATAAAGAGT	200
TGTCGGAAGA	AGAAGATAAT	GAAGAGAAGG	ATGATAAAGT	AGGCAAGAAG	250
AAGGATAAAG	AAAAGAAAGT	CAAGGCGAAT	GCGGCTGAAG	TCGCCACAAG	300
AGAGCTAGAA	GTTGAGGAAG	ACAAGAAAGT	ATCCGACGAT	GAATCAGAAG	350
AGAAAAGTAA	AAGCAAGCCA	TGGTACCCGG	ATCCTCGAAT	TCGAGCTCGG	400
TACCCGGGGA	TCCTCTAGAG	TCGACCTGCA	GGCATGCAAG	CTTAANATAA	450
TCATGGTCAT	AGCTGTTTCT	GTGTGAAATT	GTTATCNTCA	CAATTCACAC	500
AACATAC					507

SEQ ID NO. 8

SEQUENCE TYPE: nucleotide  
SEQUENCE LENGTH: 731 bp

STRANDEDNESS: double-stranded  
TOPOLOGY: linear  
MOLECULAR TYPE: cDNA to mRNA

ORIGINAL SOURCE: plant  
ORGANISM: tomato

PROPERTIES: Nematode-responsive cDNA  
MISCELLANEOUS: cDNA designated as LEMMI 11

CGGCCAGTGA	ATTCGAGGNT	NCGGGTACAT	GGCCCCATCC	TACAAGTTAC	50
CACCTCCACC	AACTCCCATT	TACAAGTCGC	CACCACCACC	AACTCCTGCC	100
TACAACTCTC	CTCCACCACC	TTACTATCTT	TACACCTCTC	CCCCTNNGGG	150
CTACCATTAC	TAAAAAGCCA	CTTCATTATA	TCGAGGTAAT	TAAGACAAAC	200
TAAAACTATT	ACTAATGATG	TGTCTAAAAT	GCAAAGCAAT	AAGTTGCTCA	250
ATTTCCCTCAT	GCAATCATT	AATATATAGA	CCTATGCAGT	CTATATTCTT	300
ATTTGGATAA	CTTTAATTAC	ATGTTCTCAT	TCACAAAATT	ATATTCTTAT	350
GCAGGAAAAG	TAAAATGTTG	AGCTTAAAGA	AAGGCATTTT	GCATTTTCGA	400
GAGACGATGA	AAAAAGAAGA	AACTATAGT	AAATAATAAG	CCCCACATAA	450
GTCGAAGTTC	TTTTGTAGCT	TCATGTTATC	TAAGCTAGTG	ATATTGTTNG	500
TACTCTATTA	TTTATATTTG	TATTTTTACT	TTTATGTCCT	TCTGTATGTT	550
TGCTCAGTTT	TAATATCCTA	GCAAAATGCA	AAGATTAATT	ATGAGATGCA	600
TAAAATAAGT	TATTACTATT	AAAAA.AAAA	AAAAJCCATGG	TACCCGGAGG	650
ATCCGNNNNN	NNTNGNGAGC	TCGGTACCCG	GGGATCCTCT	AGAGTCGACC	700
TGCAGGCATG	CAAGCTTGGC	GTAATCATGG	T		731

CLAIMS

1. A nematode-responsive, preferably nematode-induced, plant promoter which can be isolated from genomic tomato DNA, upstream of a gene thereof having a DNA sequence which corresponds to a cDNA selected from the group consisting of SEQ ID nos. 1-8, preferably SEQ ID nos. 2-8, particularly SEQ ID nos. 4, 6 and 7, quite particularly SEQ ID no. 7.

2. A nematode-induced chimaeric gene, suitable for transforming a plant to protect it against nematode infection, which comprises the following operably linked, DNA sequences:

a nematode-induced promoter, preferably the nematode-induced promoter of claim 1, that is suitable to direct transcription of a foreign DNA at least substantially selectively, preferably selectively, in specific cells of the roots, preferably in the cells of fixed feeding sites, of the plant;

a first foreign DNA that encodes a first RNA and/or protein or polypeptide which, when produced or overproduced in the specific cells of the roots, preferably in the cells of the fixed feeding sites, of the plant, either a) kills, disables or repels the nematodes when the nematodes feed from the fixed feeding sites or b) kills the specific cells of the roots, preferably the cells of the fixed feeding sites, or at least disturbs significantly their metabolism, functioning and/or development, thereby at least



disturbing significantly, and preferably ending, the ability of the nematodes to feed from the fixed feeding sites of the plant; and suitable 3' transcription termination signals for expressing the first foreign DNA in the specific root cells, preferably the fixed feeding site cells.

3. The nematode-induced chimaeric gene of claim 2 wherein the nematode-induced promoter is suitable to control transcription of the foreign DNA at least substantially selectively in the cells of the fixed feeding sites of the plant.

4. A plant cell or plant cell culture transformed with the nematode-induced chimaeric gene of claim 2 or 3.

5. A plant or its seeds consisting essentially of the plant cells of claim 4.

6. The plant of claim 5 or its seeds, in which the nematode-induced promoter directs transcription of the first foreign DNA only substantially selectively in the specific root cells, preferably the fixed feeding site cells, of the plant and which also contains a restorer chimaeric gene, preferably in the same genetic locus as the nematode-induced chimaeric gene; the restorer chimaeric gene having the following, operably linked, DNA sequences:

a second promoter, such as the nematode-repressed promoter of claim 1, which can direct transcription of a second foreign DNA in cells of

the plant where the first foreign DNA is expressed, preferably substantially selectively in cells other than the specific root cells, preferably in cells other than the fixed feeding site cells, of the plant;

a second foreign DNA that encodes a second RNA and/or protein or polypeptide which, when produced or overproduced in cells of the plant, inhibits or inactivates the first foreign DNA or the first RNA or protein or polypeptide; and suitable 3' transcription termination signals for expressing the second foreign DNA in plant cells.

7. A cell of the plant of claim 6 or a cell culture consisting essentially of the cells.

8. A process for rendering a plant resistant to nematodes, particularly sedentary endoparasitic nematodes, comprising the step of transforming the plant's nuclear genome with the nematode-induced chimaeric gene of claim 2 or 3 and optionally the restorer chimaeric gene of claim 6.

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 92/01214

**I. CLASSIFICATION OF SUBJECT MATTER** (If several classification symbols apply, indicate all)<sup>6</sup>

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 C12N15/29; C12N15/82; C12N5/10; A01H5/00  
A01N65/00

**II. FIELDS SEARCHED**Minimum Documentation Searched<sup>7</sup>

Classification System

Classification Symbols

Int.Cl. 5 C12N ; A01H ; A01N

Documentation Searched other than Minimum Documentation  
to the Extent that such Documents are Included in the Fields Searched<sup>8</sup>

**III. DOCUMENTS CONSIDERED TO BE RELEVANT<sup>9</sup>**

Category <sup>10</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
A	MOLECULAR & GENERAL GENETICS vol. 226, no. 3, May 1991, pages 361 - 366; GURR, S. J., ET AL.: 'Gene expression in nematode - infected plant roots' see the whole document ---	1-8
A	J. CELL. BIOCHEM. SUPPL. vol. 13D, 1989, page 323; NIEBEL, A., ET AL.: 'Molecular analysis of nematode induced giant cells in potato roots' * abstract M429 * --- -/-	1-8

<sup>10</sup> Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"A" document member of the same patent family

**IV. CERTIFICATION**

Date of the Actual Completion of the International Search

18 SEPTEMBER 1992

Date of Mailing of this International Search Report

29. 09. 92

International Searching Authority

EUROPEAN PATENT OFFICE

Signature of Authorized Officer

MADDOX A.D.

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	PHYTOPHYLACTICA vol. 23, no. 2, 1991, MEETING HELD APRIL 7-10, 1991. page 182; DE WEALE, D.: 'Potential of plant genetic engineering for nematode control' * abstract * ---	1-8
A	EP,A,0 298 918 (CIBA-GEIGY) 11 January 1989 see column 6 - column 7 ---	1-8
A	CHEMICAL ABSTRACTS, vol. 113, 1990, Columbus, Ohio, US; abstract no. 127723, JUN, W.: 'Preparation of transgenic plants for control of virosis' page 205 ; see abstract & CN,A,1 033 645 (FAMING ZHUANLI SHENQUING GONGKAI SHUOMINGSHU) 5 July 1989 ---	1-8
P,A	WO,A,9 204 453 (UNIVERSITY OF LEEDS) 19 March 1992 see the whole document ---	1-8

**ANNEX TO THE INTERNATIONAL SEARCH REPORT  
ON INTERNATIONAL PATENT APPLICATION NO. EP 9201214  
SA 60820**

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.  
The members are as contained in the European Patent Office EDP file on  
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information. 18/09/92

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A-0298918	11-01-89	AU-B- 620039 JP-A- 1037294	13-02-92 07-02-89
CN-A-1033645		None	
WO-A-9204453	19-03-92	AU-A- 8502391	30-03-92